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ROOF STABILITY AND ITS FORECASTING

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Разработан новый компьютерный алгоритм для оценки устойчивости кровли по длине выемочного столба лавы. Алгоритм основан на новом геомеханическом критерии. Распределения критерия получены по всей площади расчетной области. Это позволило предсказать наиболее опасные места в кровле, улучшить ее устойчивость и увеличить производительность лав.

Розроблений новий комп'ютерний алгоритм для оцінки стійкості покрівлі вздовж виймального стовпа лави. Алгоритм заснований на новому геомеханічному критерії. Розподілення критерію є отриманими вздовж усієї площі розрахункової області. Це дозволило завбачити найбільш небезпечні місця в покрівлі, поліпшити її стійкість та збільшити продуктивність лав.

Introduction

Good stability of the roof is a crucial factor for a longwall panel productivity. Roof falls cause hazard, delay coal extraction process, cut its productivity and deteriorate quality of the coal. The roof stability varies across a longwall panel area because of diversity of rock strength, of roof stratigraphic sequence, of ground pressure in the abutment zone both along the longwall face and onward of panel during its advance. An algorithm and computer code have been developed to predict the roof stability with consideration of all the factors mentioned above.

Stability criterion

The roof stability criterion S has been calculated according the formula:

$$S = kR/\sigma \qquad (1)$$

Where k is an empirical factor;
R is reduced strength of the roof;
σ is the ground pressure in front of a panel in the abutment zone.

Formula (1) differs from well known prototypes by accounting technological factors and stratigraphical sequence. The empirical factor takes into account technological parameters and specifications, namely initial and maximum support resistance, rate of the face advance, time period between roof exposing and its supporting, distance between the face and the tip of canopy, etc. Strength of the roof has been reduced to the roof exposure level according the formula (Chugay, 1978):

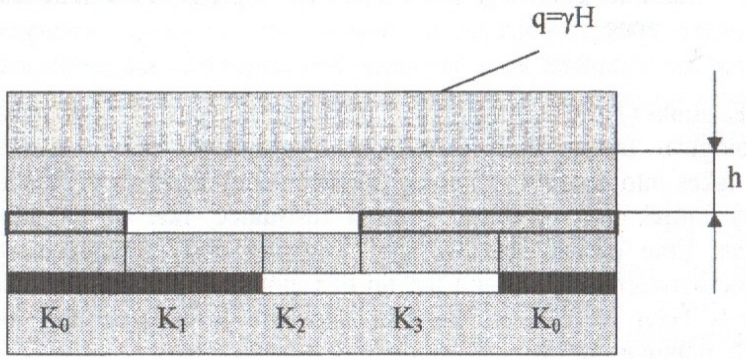
$$R = \frac{\Sigma R_i h_i / y_i}{\Sigma h_i / y_i} \qquad (2)$$

where R_i is strength of i-th rock layer in situ (fracturing of the rock mass is considered);
h_i is thickness of the layer;
y_i is distance from the center of the layer to the center of the coal seam.

This formula accounts the position of every rock layer relatively to coal seam. The closer the layer the more its investment in overall roof stability. During calculation, all rock layers are accounted in the diapason of 6 thickness of the coal seam.

Ground pressure calculation

To calculate ground pressure, let us to use the next model (Nazimko, 1990). Rock strata was considered as a plate with a thickness h (fig. 1). This plate is loaded by overburden pressure q and lays upon a base which has been comprised from the coal seams and waste rock situated below. Initial rigidity of the base K_0 is maximum. The more coal seams extracted and the closer they to the plate the less the rigidity K_I is.



$K_0 > K_3 > K_1 > K_2$

Fig. 1. Model of rock strata

Vertical stress distribution in extracted coal seam's plane or horizon has been calculated according equation:

$$\frac{\partial^4 w}{\partial x^4} + 2\frac{\partial^4 w}{\partial x^2 \partial y^2} + \frac{\partial^4 w}{\partial y^4} = \frac{q}{Df} - \frac{Kw}{Df} \qquad (3)$$

where w is subsidence or vertical sinking of the plate;
x, y are coordinates in horizontal plane;
q is normal to the plate surface load;
K is rigidity of the fundament;
Df is flexural rigidity of the plate:

$$Df = \frac{Eh^3}{12(1-v)'}$$

where E and v are elasticity modulus and Poisson ratio of the plate,
h is– thickness of plate.

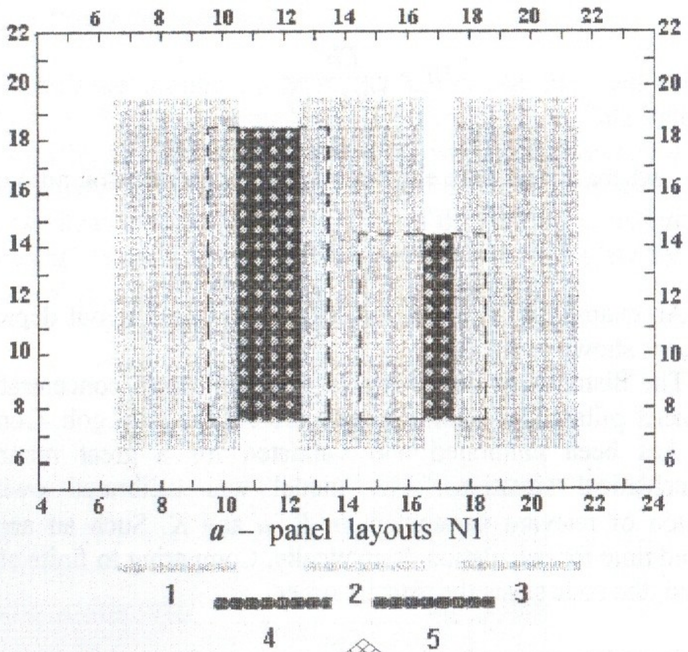
An example of stress distribution for a panel layout depicted in fig. 2,*a* is shown in fig. 2,*b*.

The distribution demonstrates peaks of stress concentration in interpanel pillars and abutment zone around the total gob. Computer code has been calibrated and validated for a great number of geomechanical situations. The model was calibrated owing to selection of relevant parameters h, E, μ and K. Such an approach reduced time for calculation dramatically. Comparing to finite element method, the code saves the time by order.

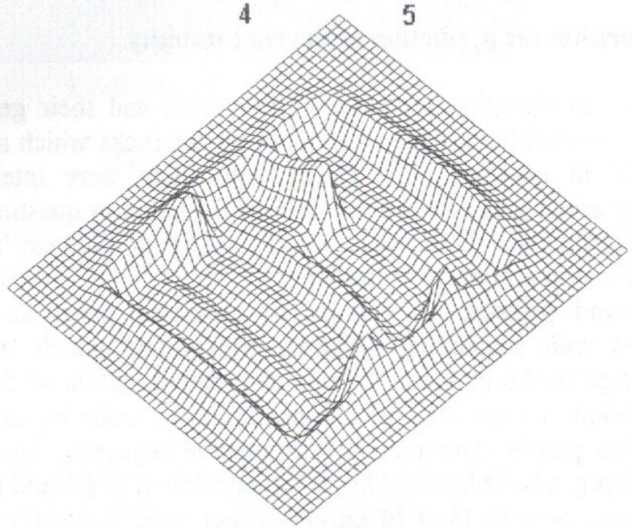
The algorithm for prediction of the roof stability

First stratigraphic sequence of the strata and their geological properties should be analyzed and input for the rocks which surround the panel in question (fig. 3).The input data were interpolated according initial grid covered the field of the panel in question. Then strength of the roof should be reduced to the roof exposure in every node of the grid according formula (2).

Ground pressure in vicinity of predicted panel should be calculated with accounting of stress background which has been accumulated to the moment. To this end, determination of the stress redistribution in every node of the grid are to be made by simulation of previous panels extracting in retrospective sequence. Final stress distribution is a boundary condition for calculation of ground pressure in abutment zone in front of moving panel, roof stability of which should be predicted.



a – panel layouts N1



b – stress distribution

Fig. 2. Stress distribution for the typical panel layouts

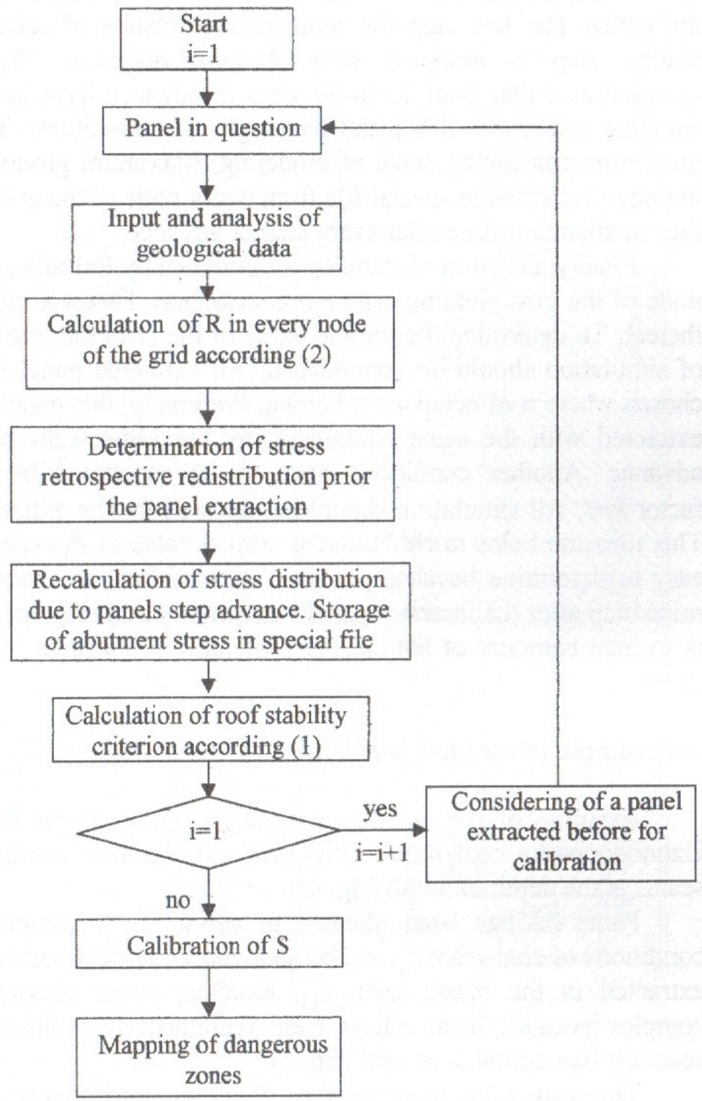


Fig. 3. Algorithm of roof stability prediction

The ground pressure is calculated after every step of advance of the panel. The less step the more precise results of calculation. In reality, step is assigned from 25-50m diapason. Practice has demonstrated that from 15 to 30 steps of advance have been used to simulate extraction of a panel by length of 800-1500m. This is the most time consuming stage of modeling. Maximum ground pressure has been collected in special file from every node of the grid along the face in abutment zone after every step of advance.

Finally, criterion of stability is calculated by formula (1) in every node of the grid yielding criterion distribution. Factor k must to be 1 thereat. To determine the critical value of the criterion, the next stage of simulation should be commenced. An extracted panel have to be chosen where roof behavior is known. Preferably, this panel should be extracted with the same equipment, by the same team and rate of advance. Another conditions have to be accounted by empirical factor $k \neq 1$. All simulation should be repeated for the extracted panel. This measure helps to calibrate the critical value of the criterion. It is easy to determine because positions of roof falls are known on the mine map after 'calibrating' panel extraction. Final stage of prediction is to map contours of anticipated roof falls on the area of predicted panel.

An example of roof fall prediction

Example of the stability evaluation is shown for the case of Uzhnodonbaska coal mine. This mine extracts two contiguous coal seams at the depth of 340m (fig. 4).

Panel 22 has been planned to extract in a complex ground conditions of coal seam c_{11} in Uzhnodonbaska mine. Four panels were extracted in the upper seam c_{13}. Residual stress distribution was complex because local pillars were remained. In addition, roof of seam c_{11} was complex as well (fig. 5).

The seam splits in some areas. Previous practice has shown that roof falls occurred when the rock middleman became critically thin. Fig. 6 depicts strength distribution across panel 22 area. It

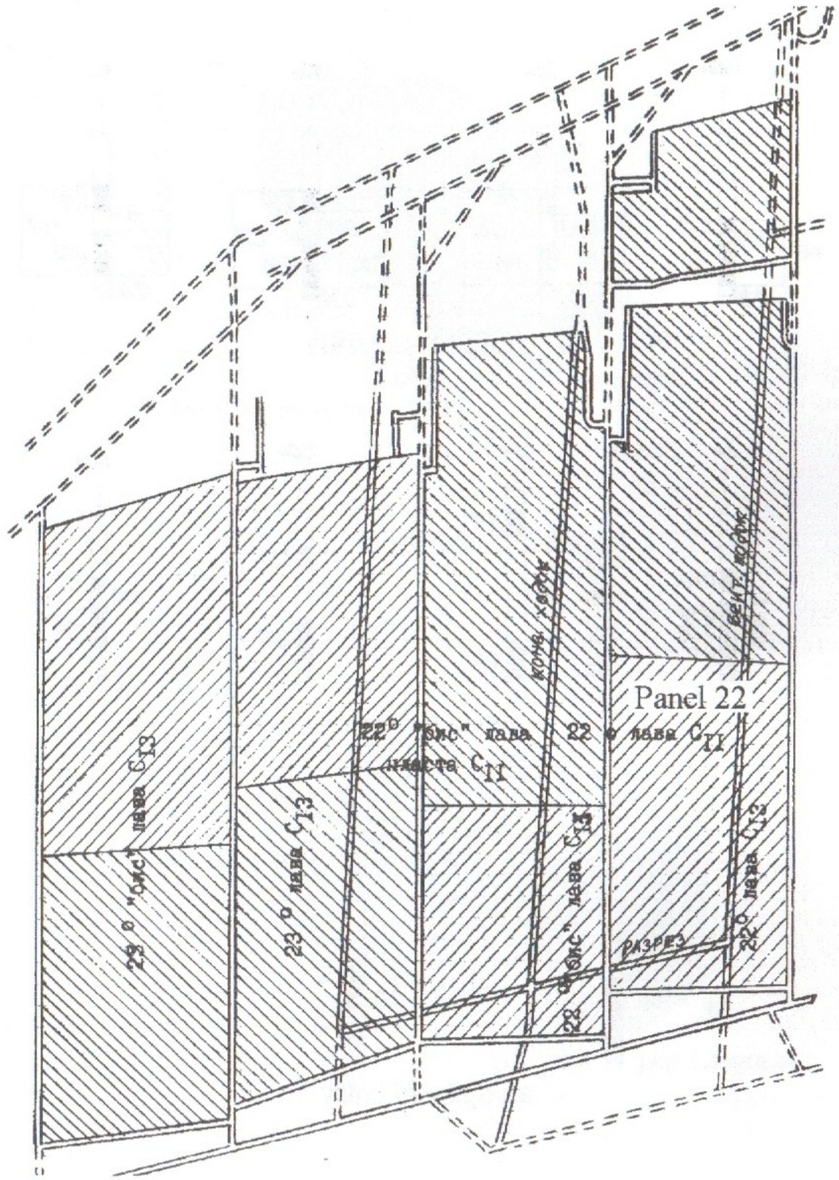


Fig. 4. Panel layout

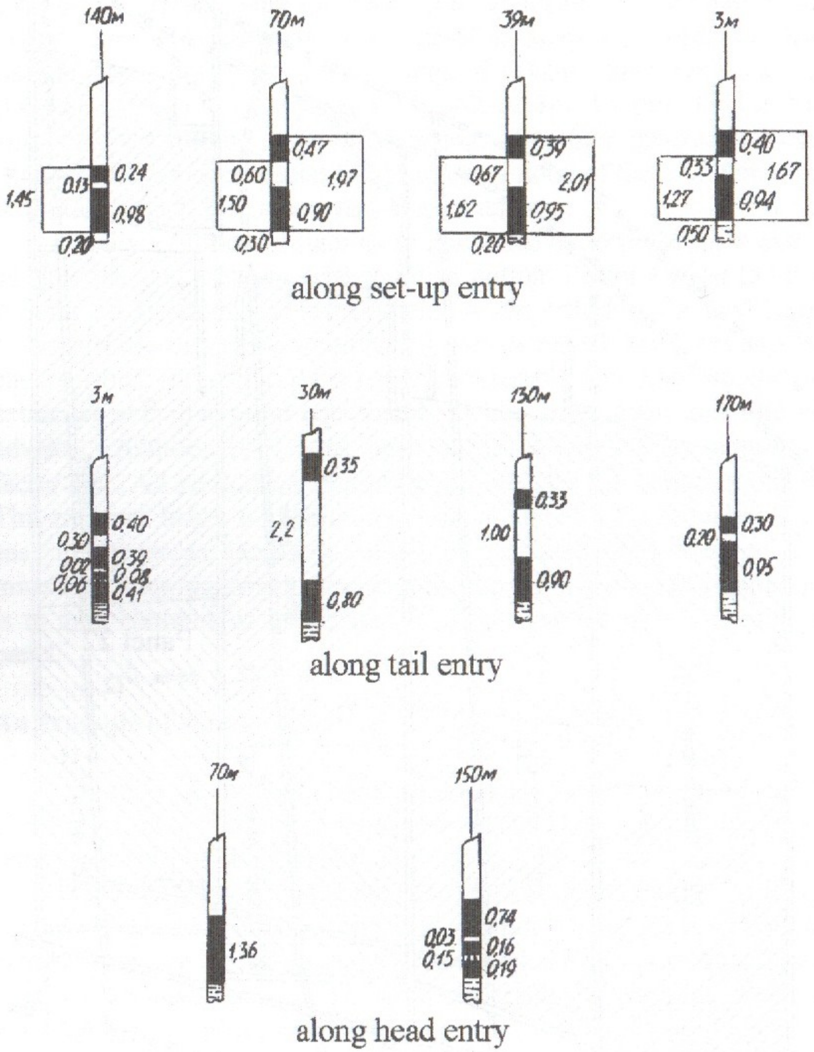


Fig. 5. Patterns of stratigraphical sequences

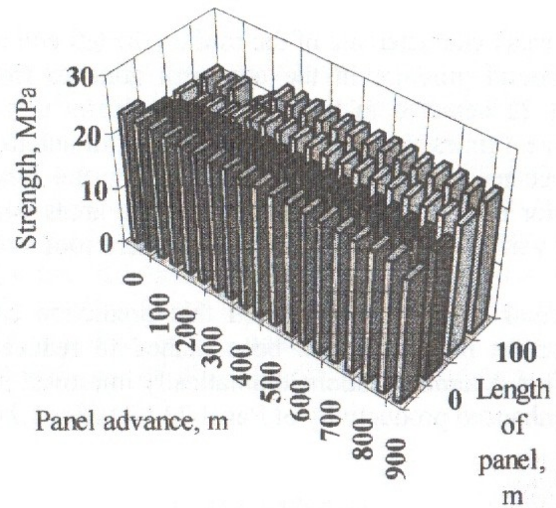


Fig. 6. Roof strength distribution

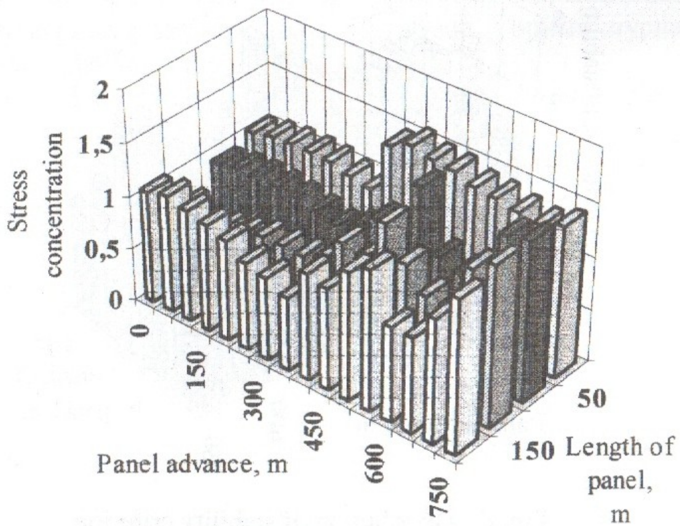


Fig. 7. Stress distribution in front of moving panel

demonstrates weak characteristic of the roof on the left end of the area especially. Ground pressure in the abutment zone in front of the moving panel 22 depicted in the fig. 7. It indicates that abutment pressure deviate 4 times from place to place. As it turned, the pressure distribution became critical for roof stability. In the other words, minimum factor of roof stability occurred at the areas where stress concentration was maximum (fig. 8) but not where roof strength was minimum.

Actual roof behavior proved this prediction completely. Special precaution measures have been planed to reduce roof fall probability. This recommendations dramatically improved stability of the roof and enhanced productivity of Panel 22 by factor 1,2-1,3.

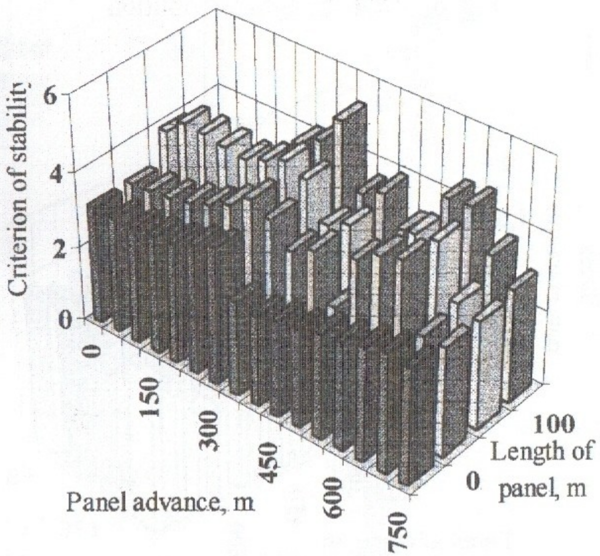


Fig. 8. Distribution of stability criterion

Conclusion

New algorithm has been developed to predict roof stability in a longwall panel. The roof stability may be predicted across a longwall panel area with considering of rock strength diversity, of roof stratigraphic sequence variability, of stress redistribution history before extracting panel in question, of ground pressure fluctuation in the abutment zone both along the longwall face and onward of panel during its advance. It takes 2-4 hours in PC Pentium-100 to solve the problem and a couple of days to collect and prepare initial data and to predict roof stability in a panel. An actual experiment has corroborated validity of the algorithm for complex ground and technological conditions.

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